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(54) IMPROVEMENTS IN OR RELATING TO EXTRUSION

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, LONDON, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the forming of materials by extrusion.

In extrusion a workpiece is subjected to pressure in a container so that the workpiece is extruded from the container through an orifice defining the product cross section. Pressure may be applied on the workpiece mechanically, as in conventional extrusion by a ram acting on the workpiece in a container. Alternatively, as in hydrostatic extrusion, liquid may be pressurised about the workpiece in the container to effect extrusion of the workpiece.

One feature which is a practical limitation in carrying out such an extrusion process particularly when applied to metals, is that the pressure required to carry out extrusion is dependent on the extrusion ratio, the extrusion ratio being defined as the cross sectional area of the workpiece relative to the cross sectional area of the extruded product.

Even in the case of easily worked metals high extrusion ratios can only be achieved by the application of prohibitively high pressures on the workpiece in the container. The manufacture of containers which can withstand such high pressures is difficult and costly.

It is an object of the present invention to provide an extrusion process in which this difficulty is avoided.

In one aspect, the present invention provides a process of continuously extruding material which comprises the steps of feeding material into one end of a passageway formed between first and second members with the second member having a greater surface area for engaging the material than the first member, said passageway having a blocked end remote from said one end and having at least one die orifice associated with said blocked end, and moving the passageway defining surface of the second member relative to the passageway defining surface of the first member in a direction towards the or each die orifice from said one end to said blocked end such that the frictional drag of the passageway defining surface of the second member draws the material substantially in its entirety through the passageway and through the or each die orifice.

The passageway may be formed between a wheel member having an endless groove therein and a shoe member covering a part of the length of the groove, and wherein the wheel member is rotated in a direction to drag material through the passageway and the or each die orifice.

In conventional and hydrostatic extrusion, the size of workpiece which can be accommodated in the extrusion container governs the length of extruded product which can be formed in a single operation. The workpiece diameter is limited by the extrusion ratio which can be achieved at the designed working pressure of the extrusion container. Therefore, increase of product length can only be achieved by increase in the length of the extrusion container to contain the workpiece, which adds to the difficulty and cost of manufacture of such containers.

It is a further object of the present invention to provide apparatus for carrying out the process of the present invention, preferably with the capability of handling a continuous feed.

Extrusion apparatus according to the invention comprises movable and fixed members defining an elongate passageway therebetween, an abutment member arranged to project into and block the passageway, means defining at least one die orifice leading from the passageway and associated with the abutment member, means for continuously feeding feeding material to be extruded into the passageway at a point spaced from the abutment

member, the amount of the surface area of the passageway defined by the movable member being greater than the amount of the surface area of the passageway defined by the fixed member, whereby upon movement of the passageway defining surface of the movable member relative to the passageway defining surface of the fixed member the material fed into the passageway is moved by frictional drag with the surface of the passageway in the movable member towards the abutment member and is thereby extruded substantially in its entirety through the or each die orifice.

A particular form of extrusion apparatus in accordance with the invention comprises a wheel member having an endless groove therein, a shoe member covering part of the length of the groove and forming a passageway therewith, an abutment member projecting from the shoe member into the groove and blocking one end of the passageway, the wheel member being rotatable relative to the shoe member, at least one die orifice associated with the abutment member, and means for feeding material to be extruded into the end of the passageway remote from the abutment member so that upon rotation of the wheel member the material is carried along in the groove by frictional drag in the direction towards the abutment member and is thereby extruded through the or each die orifice. The die orifice or orifices may be provided in the leading face of the abutment member. Alternatively the abutment member may be of solid form, the die orifice or orifices being provided in the face of the shoe member in front of the abutment member. The die orifices may be defined by die insert members fitted in housings.

A plurality of shoe members may co-operate with the groove at spaced intervals.

Our Patent Specification Serial No. 1,289,482 relates to extrusion apparatus in which a bulk compressive stress is applied in material to be extruded so as to feed the material into the region forward of the working face of a tool member which is moved so that the material in this region is subjected to an additional compressive stress and is formed through a die orifice associated with the tool member under the influence of the additional compressive stress in combination with the bulk compressive stress acting in the material.

A preferred form of extrusion apparatus as disclosed in said specification No. 1,289,482 employs a rotary tool member having an end face with a tooth member projecting therefrom. The tool member is rotated about an axis transverse to the end face having the projecting tooth member so that the tooth member is moved in a circular path with its forward working face in pressure contact with material in the region of the end face of the tool member. The material is subjected to a bulk compressive stress to feed the material continuously into the region of the end face of the tool member. The material forward of the working face of the tooth member is subjected to an additional compressive stress so that the material is formed through a die orifice associated with the tooth member under the influence of the additional compressive stress in combination with the bulk compressive stress acting in the material.

Apparatus in accordance with the present invention may be employed for the pressure feeding of material into the region of the end face of the tool member in apparatus of the kind disclosed in said Specification No. 1,289,482.

In the form of apparatus according to the present invention which comprises a rotary wheel member, material fed along the groove is worked by a rotary tool member of the kind disclosed in specification No. 1,289,482, the tool member being fitted in a housing in the shoe member with the end face of the tool member open to the region of the groove adjacent the face of the abutment member.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a part-sectional longitudinal elevation of extrusion apparatus in accordance with the invention,

Figure 2 is an "exploded" isometric view of the apparatus shown in Figure 1,

Figure 3 is a modification of the arrangement shown in Figures 1 and 2,

Figure 4 is a sectional elevation of a further form of apparatus in accordance with the invention,

Figures 5, 6, 7, 8 and 9 are details in isometric form of modifications of the apparatus of Figure 4,

Figure 10 is a sectional detail of a third form of apparatus in accordance with the invention,

Figure 11 is a section along the line XI—XI in Figure 10.

The extrusion apparatus shown in Figures 1 and 2 comprises a wheel 1 rotatably mounted on a shaft 2. The wheel 1 has a square cross-section circumferential groove 3 machined around its outer edge, the groove being therefore a square surface of revolution about the axis of the wheel. A shoe member 4 fits closely against the edge of the wheel 1. An abutment member 5 formed on the under side of the shoe member 4 projects into the circumferential groove 3 and is complementary in shape to the groove cross section so as to block the groove with a sliding fit. The abutment member 5 has an extrusion orifice 6. A chamber 7 integrally formed with the shoe member 4 has a bore 8 connecting with the circumferential groove 3

in the wheel 1. A sealing block 9 formed on the underside of the shoe member 4 at the opposite end to the abutment member 5 projects into and is a close sliding fit in the circumferential groove 3 in the wheel 1.

Material 10 to be extruded, which material can be metal, is fed under pressure through the bore 8 of the chamber 7 and fills that part of the groove 3 in the wheel 1 underneath the shoe member 4 between the abutment member 5 and the sealing block 9 of the shoe member 4.

The material to be extruded may be forced through the chamber 7 into the groove 3 by a ram acting in the bore 8 of the chamber 7. After extrusion of the material within the chamber 7 the ram is withdrawn and further material is supplied to the chamber 7, for example from a continuous casting unit. Alternatively the material may be fed as powder either intermittently by a ram or continuously by screw feeders.

The wheel 1 is rotated clockwise as shown by the arrow 11 in Figure 1. The material 10 in the circumferential groove 3 beneath the shoe member 4 is carried forward towards the abutment member 5 by the frictional drag of the walls of the circumferential groove 3. Thus pressure is generated in the material in the circumferential groove 3, so that the material is extruded through the orifice 6 in the abutment member 5. Also the rotation of the wheel 1 drags material under a transverse shearing action from the bore 8 of the chamber 7 so that a continuous extrusion of the material is obtained. Material drawn from the chamber 7 by rotation of the wheel 1 is continually replaced by the continuous feed of fresh material into the chamber 7.

With powdered feed the pressure applied on the material in the circumferential groove 3 results in compaction of the powdered material. Further compaction of the powdered material occurs during extrusion through the extrusion orifice 6 so that a solid extruded product is obtained.

The circumferential groove 3 in the wheel 1 in conjunction with the shoe member 4 may be regarded as forming a passageway or channel having four walls. The three walls of the channel defined by the side walls and base of the circumferential groove 3 move continuously towards the abutment member 5. The fourth wall of the channels, defined by the under surface of the shoe member 4 is stationary. As described above the three moving walls of the circumferential groove 3 carry the material 10 by frictional drag, towards the abutment member 5. The material slides over the stationary fourth wall formed by the under surface of the shoe member 4. Thus if the frictional coefficients are the same for all four walls and since the stationary wall formed by the under surface of the shoe member 4 is opposing the frictional drag applied on the material by the base of the circumferential groove 3, in effect the frictional drag of the two side walls of the abutment member 5.

The resultant force acting on the material 10 in the direction towards the abutment member 5 is thus:

$$2.l.w.k.$$

where:

- l=the circumferential length of the groove 3 below the shoe member 4 which is filled with the material to be extruded,
- w=the width of the side walls of the circumferential groove 3,
- k=the shear strength of the material being extruded.

This force of 2.l.w.k. must produce a load on the face of the abutment member 5 of PA where

- P=the pressure required for extrusion of the material
- A=the cross sectional area of the abutment member 5 which is the same as the cross sectional area of the circumferential groove 3.

In the case of a groove 3 of square cross section $A=w^2$ and therefore $PA=Pw^2$.

Thus under extrusion conditions

$$2.l.w.k=Pw^2$$

Therefore

$$l.w=\frac{Pw^2}{2k}=\frac{Pw^2}{Y}$$

where $Y=2k$=the yield strength of the material. It follows that

$$\frac{1}{w}=\frac{P}{Y}$$

This expression enables the calculation of the dimensional parameters of apparatus as described above for extrusion of a selected material.

For example considering the extrusion of copper which may be taken as having a yield strength of 3 tons per square inch.

The use of a wheel 1 having a square cross section circumferential groove of ½″ side width and an extrusion orifice 6 in the abutment member 5 of 0.075 inches diameter results in an extrusion ratio of approximately 55:1 which will require an extrusion pressure of about 100 tons per square inch.

Therefore:

$$\frac{1}{0.5}=\frac{100}{3}$$

and

$$l = \frac{50}{3}$$

=approximately 17 inches

If a shoe member 4 having a length of about one quarter of the circumference of the wheel 1 is employed this fixes the required diameter of the wheel 1 at about 21 inches.

Figure 3 shows a second arrangement for the continuous extrusion of bar. The arrangement of Figure 3 is similar to that of Figures 1 and 2 and similar parts in the two arrangements are referred to by the same reference numerals.

In the arrangement of Figure 3 the chamber 8 is omitted from the shoe member 4. A bar 11 of feed material is fed continuously into the circumferential groove 3 in the edge of the wheel 1. The bar 11 is continuously carried forward in the groove 3 beneath the shoe member 4 towards the abutment member 5 and the leading end of the bar 11 is continuously extruded through the orifice 6 in the abutment member 5. In this case no external pressure feed is required for the bar 11 and the arrangement is particularly suitable for the extrusion of powdered material which may be fed into the groove 3 by continuous tamping or by a screw feeder. A gravity feed may suffice although measures to ensure free flow may be advisable. When starting operation with a new feed, a powdered material may not be mixed immediately by the moving surfaces. However, with assistance if necessary, the particles will ultimately pack in a manner which renders frictional drag effective. For a solid feed, such as the bar 11 a roller may be used immediately in advance of the shoe member 4 for pressing the bar into the groove.

The apparatus shown in Figure 4 is of the same basic form as Figures 1 and 2 and again similar parts are referred to by the same reference numerals. The apparatus of Figure 4 comprises a wheel 1 rotatably mounted on a shaft 2. The wheel 1 has a circumferential groove 3 machined around its outer edge. Two shoe members 4 are fitted closely against the edge of the wheel 1. An abutment member 5 is formed on the underside of each shoe member 4 projecting into the circumferential groove 3 on the wheel 1. A die insert 6 is fitted in a housing 7 forward of the abutment member 5. The die insert 6 connects with an outlet passageway 8 leading radially through the shoe member 4. In use of the apparatus shown in Figure 4 a bar 9 of feed material is fed continuously into the circumferential groove 3 below each shoe member 4. The wheel 1 is rotated anti-clockwise as shown by the arrow 10. The walls of the circumferential groove 3 exert a frictional drag on each of the bars 9 of feed material. Each bar 9 is drawn along in the groove 3 below the corresponding shoe member 4 towards the abutment member 5 on the shoe member 4. Thus pressure is generated in the material of the bars 9 within the circumferential groove 3 below the shoe members 4 and the leading end of each bar 9 is extruded through the die insert 6. The extruded product passes out radially through the outlet passageways 8.

Although Figure 4 shows the use of two shoe members 4 in conjunction with the wheel 1 a larger number of shoe members 4 can be employed depending on the diameter of the wheel 1. For example three shoe members 4 may be used spaced at 120° intervals around the circumference of the wheel 1. In production equipment there may be several wheels 1 mounted on a common shaft each wheel 1 having a plurality of shoe members 4. An arrangement using shoe members in diametrically opposed relationship serves to balance the thrusts at the wheel member bearings of the radially inward forces generated by the compression of material at the abutment member.

Each shoe member 4 may have a single die insert 6 as shown in Figure 4. Alternatively each shoe member 4 may be fitted with a number of die inserts 6. Figure 5 shows two die inserts 6 arranged one in front of the other forward of the abutment member 5. Figure 6 shows four smaller die inserts 6 arranged in a group forward of the abutment member 5. Die inserts having orifices of non-circular cross section may be employed. In Figure 7 the die insert 6 has an orifice 11 of rectangular form extending parallel to the face of the abutment member 5. In this arrangement the length of the orifice 11 in the die insert 6 is governed by the width of the circumferential groove 3. In Figure 8 the die insert 6 has a rectangular orifice 11 which extends at right angles to the face of the abutment member 5. The arrangement of Figure 8 enables an orifice of greater length to be employed than in the arrangement of Figure 7. Figure 9 shows a porthole die insert 6 enabling the extrusion of a tubular product.

In the arrangement of Figures 1 and 2 and of Figure 3 the abutment member 5 may be provided with a multiplicity of die orifices 6 which may be in the form of die inserts fitted in housings in the abutment member 5.

Figures 10 and 11 are details of an extrusion apparatus again including a wheel 1 having a circumferential groove 3 around its outer edge. A shoe member 4 is fitted closely against the edge of the wheel 1. An abutment member 5 is formed on the underside of the shoe member 4 projecting into the circumferential groove 3 on the wheel 1. A radial drilling 12 in the shoe member 4 forward of the abutment member 5 houses a rotary tool member 13. The lower end face 14 of the tool member 13 has a tooth shaped projec-

tion 15 and a die insert 16 is fitted in the face 14 of the tool member 13. A guide member 17 having a wedge shaped base 18 with a cylindrical boss 19 is fitted in the groove 3 of the wheel 1 in front of the abutment member 5.

In use of the apparatus of Figures 10 and 11 the wheel 1 is rotated anticlockwise relative to the shoe member 4 in the direction of the arrow 20 in Figure 10. The walls of the groove 3 in the wheel 1 exert a frictional drag on feed material 21 in the groove 3. Thus rotation of the wheel 1 feeds the material towards the abutment member 5 of the shoe member 4 and the guide member 17 distributes the material 21 into the region of the lower end face 14 of the rotary tool member 13. An overall compressive stress is also generated in the material 21 within the circumferential groove 3 of the wheel 1 below the tool member 13. Rotation of the tool member 13 in the direction of the arrow 22 in Figure 11 drives the projection 15 through the material 21 in the groove 3 below the tool member 13. The material 21 forward of the projection 15 is subjected to an additional compressive stress which, in combination with the overall compressive stress acting in the material 21 causes extrusion through the die insert 16.

In all the embodiments, the fit of the abutment member in the groove is not necessarily critical. Some material may extrude as "flash" through clearances but since such flash will be largely the outer skin in the case of a solid feed the separation of this skin from the product may even be advantageous if the feed has surface impurities. It will further be appreciated that the groove shape need not be square or rectangular; instead of the side walls being parallel they may be angled and form, for example, a truncated V groove.

WHAT WE CLAIM IS:—

1. A process of continuously extruding material which comprises the steps of feeding material into one end of a passageway formed between first and second members with the second member having a greater surface area for engaging the material than the first member, said passageway having a blocked end remote from said one end and having at least one die orifice associated with said blocked end, and moving the passageway defining surface of the second member relative to the passageway defining surface of the first member in a direction towards the or each die orifice from said one end to said blocked end such that the frictional drag of the passageway defining surface of the second member draws the material substantially in its entirety through the passageway and through the or each die orifice.

2. A process as claimed in claim 1 wherein the first member comprises a shoe member and the second member comprises a wheel member and the passageway is formed between the wheel member which has an endless groove therein and the shoe member which covers a part of the length of the groove, and wherein the wheel member is rotated in a direction to drag material through the passageway and the or each die orifice.

3. Extrusion apparatus comprising movable and fixed members defining an elongate passageway therebetween, an abutment member arranged to project into and block the passageway, means defining at least one die orifice leading from the passageway and associated with the abument member, means for continuously feeding material to be extruded into the passageway at a point spaced from the abutment member, the amount of the surface area of the passageway defined by the movable member being greater than the amount of the surface area of the passageway defined by the fixed member, whereby upon movement of the passageway defining surface of the movable member relative to the passageway defining surface of the fixed member the material fed into the passageway is moved by frictional drag with the surface of the passageway in the movable member towards the abutment member and is thereby extruded substantially in its entirety through the or each die orifice.

4. Extrusion apparatus comprising a wheel member having an endless groove therein, a shoe member covering part of the length of the groove and forming a passageway therewith, an abutment member projecting from the shoe member into the groove and blocking one end of the passageway, the wheel member being rotatable relative to the shoe member, at least one die orifice associated with the abutment member, and means for feeding material to be extruded into the end of the passageway remote from the abutment member so that upon rotation of the wheel member the material is carried along in the groove by frictional drag in the direction towards the abutment member and is thereby extruded through the or each die orifice.

5. Extrusion apparatus according to claim 4 wherein the groove is of uniform cross sectional shape throughout its length and is defined by a surface of revolution about the axis of the wheel member.

6. Extrusion apparatus according to claim 4 or 5 wherein the groove is formed circumferentially in the outer edge of the wheel member.

7. Extrusion apparatus according to any of claims 3 to 6 wherein the passageway has a uniform cross sectional shape throughout its length.

8. Extrusion apparatus as claimed in any of claims 3 to 7 wherein said die orifice or orifices is or are provided in the leading face of the abutment member.

9. Extrusion apparatus as claimed in any

of claims 3 to 7 wherein said abutment member is of solid form, said die orifice or orifices being provided adjacent the abutment member and in the member to which the abutment member is fixed or from which it projects.

10. Extrusion apparatus as claimed in claim 8 or 9 wherein the or each die orifice is formed by a die insert member fitted in a housing in the member in which the or each die orifice is to be provided.

11. Extrusion apparatus as claimed in claim 4 or 5 wherein a plurality of shoe members co-operate with the groove at spaced intervals.

12. Extrusion apparatus as claimed in claims 4 or 5 wherein a tool member having a material working face is provided for operation on material in the groove of the wheel member in the region adjacent the abutment member, means being provided for moving said tool member in a closed cyclic path so that the material in the groove adjacent the abutment member is subjected to additional compressive stress by the working face of the tool member whereby the material is extruded through the die orifice or orifices under the influence of the additional compressive stress in combination with the bulk compressive stress set up in the material within the groove by rotation of the wheel member.

13. Extrusion apparatus as claimed in claim 4 or 5 wherein a rotary tool member having an end face with a tooth member projecting therefrom and a die orifice associated with the tooth member is fitted in a housing in the shoe member with the end face of the tool member open to the region of the groove adjacent the face of the abutment member, means being provided for rotating the tool member about its axis transverse to the end face having the projecting tooth member so that the tooth member is moved in a circular path with its forward working face in pressure contact with the material in the region of the groove adjacent the face of the abutment member whereby the material forward of the working face of the tooth member is subjected to an additional compressive stress so that the material is extruded through the die orifice under the influence of the additional compressive stress in combination with the bulk compressive stress set up in the material within the groove by rotation of the wheel member.

14. Extrusion apparatus as claimed in claim 13 wherein a guide member is provided for distributing to the end face of the rotary tool member, the material in the region of the groove adjacent the face of the abutment member, said guide member having a wedge shaped base which is located at the bottom of the groove and tapering away from the face of the abutment member, the base of the guide member having an upstanding boss the end face of which bears centrally on the end face of the tool member so that the tooth member which projects from the end face thereof rotates around the end of the boss of the guide member as the tool member is rotated.

15. Extrusion apparatus substantially as hereinbefore described with reference to Figures 1 and 3 of the accompanying drawings.

16. Extrusion apparatus substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

17. Extrusion apparatus substantially as hereinbefore described with reference to Figures 4 to 9 of the accompanying drawings.

18. Extrusion apparatus substantially as hereinbefore described with reference to Figures 10 and 11 of the accompanying drawings.

19. An extrusion process as claimed in claim 1, substantially as hereinbefore described.

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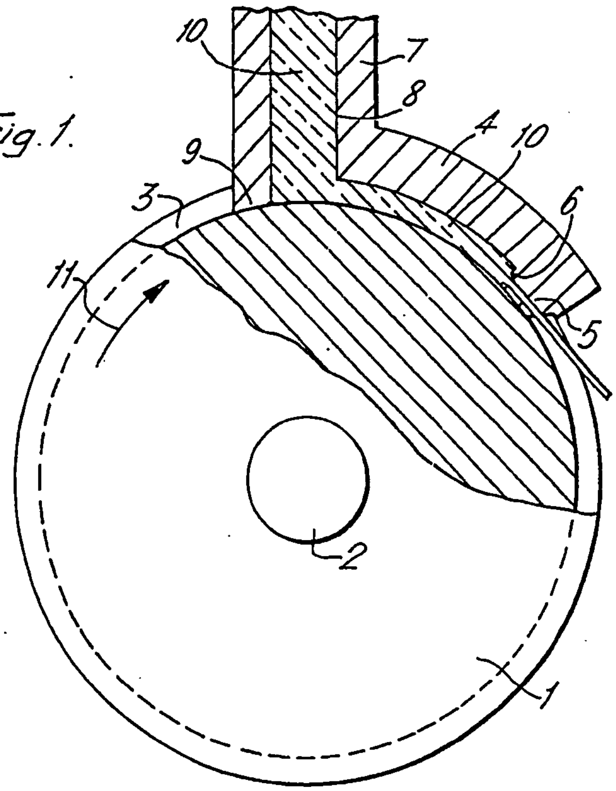
Fig. 1.



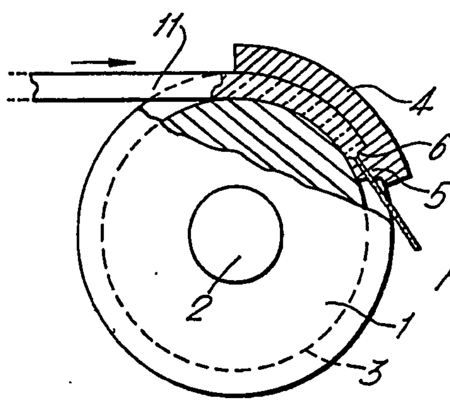


Fig. 3.

Fig. 2.

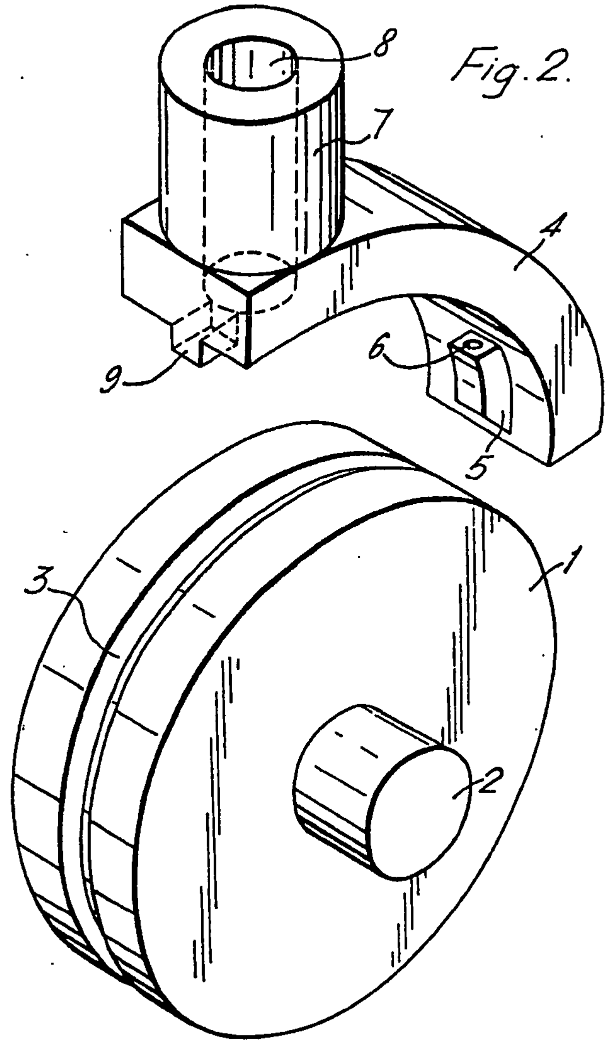


Fig. 4.

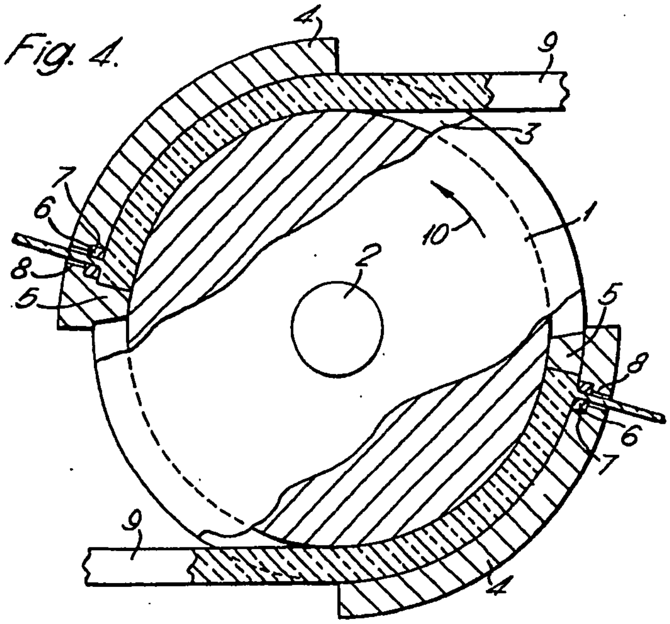


Fig. 5.

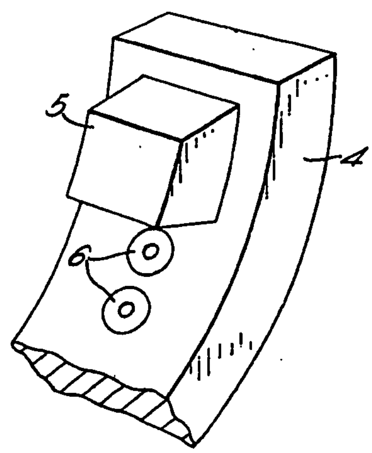


Fig. 6.

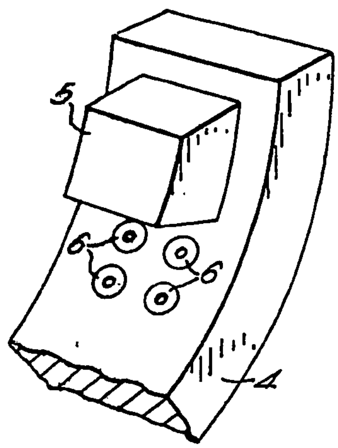


Fig. 7.

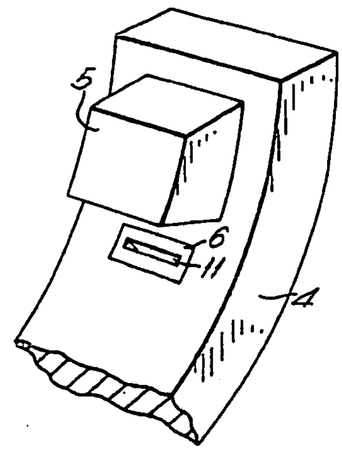


Fig. 8.

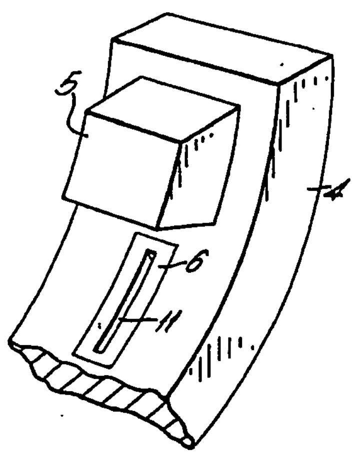


Fig. 9.

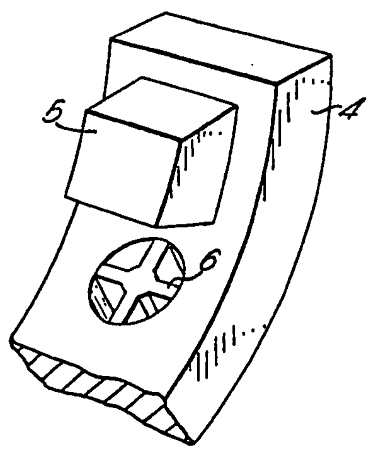


Fig. 10.

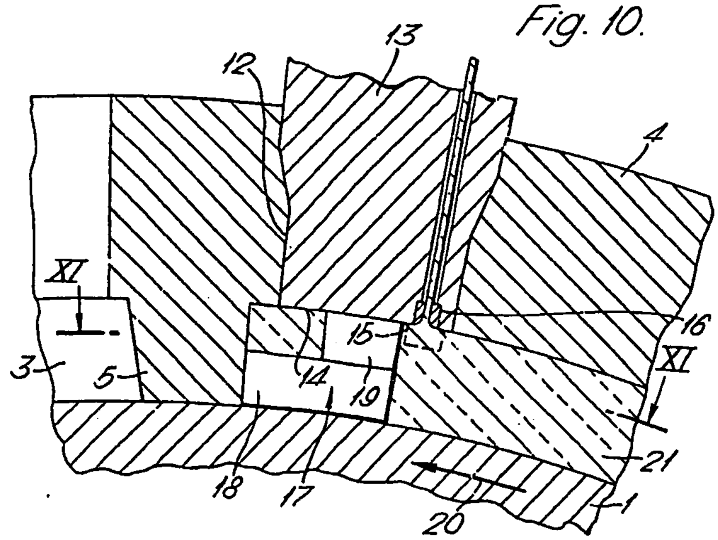


Fig. 11.